$$A = W\left[\frac{R^2 - r^2}{2r^2(\log R - \log r)} - 1\right],$$

W being the weight of water, in grammes, discharged in a second, r the radius of the jet in turns of the micrometer-screw (6·8 turns of which correspond to 1 centim.), R being the radius of the aspirating tube.

The results obtained by observation accorded well with those given by this equation, so long as the value of R did not exceed the limit within which the suppositions regarding the motion of the air hold good.

The question was considered whether the results might not be brought into even closer accord with theory by the assumption that a slipping action takes place between the air and the water-jet on the one hand, and between the air and the tube on the other, instead of the assumption previously made that the air adhered alike to the water and to the tube in its passage. The result of the calculation, however, led to no nearer approximation; and, finally, experiments with other materials for the tube and other gases (namely, coal-gas and carbonic anhydride) were made, without resulting in any marked difference from the results obtained with air and glass.

II. "An Inquiry into the Cause of the slow Pulse in Jaundice." By J. Wickham Legg, M.D., Demonstrator of Morbid Anatomy in St. Bartholomew's Hospital. Communicated by J. Burdon Sanderson, M.D., Professor of Physiology in University College, London. Received February 24th, 1876.

It has long been known to physicians that the pulse of patients jaundiced and free from fever is often slow. But I am not acquainted with any definite investigation into this subject until about thirteen years ago, when Röhrig published his researches upon the influence of the bile upon the heart*. He was the first to find out that the bile-acids, not the pigments nor the cholestearin, had the power to render the pulse slow. He formed the opinion that this slow pulse was caused by a paralysis of the cardiac ganglia, because the pulse became slow after the injection of the bile-acids into the jugular vein, even when the vagi had been cut, and because the heart of the frog, cut out and plunged into a solution of bile-acids, beat a less number of times than when cut out and immersed in serum.

The following year Traube published an altogether different explanation†. It is well known that the bile-acids have the power of dissolving

* 'Arch. f. Heilkunde,' 1863, p. 385. Also in an Inaugural Dissertation, "Ueber den Einfluss der Galle auf die Herzthätigkeit," Leipzig, 1863.

† 'Berliner klinische Wochenschrift,' 1864, No. 9 and 15; also in 'Gesammelte Beiträge' (Berlin, 1871), Bd. i. p. 366.

the blood-corpuscles. If these bile-acids, therefore, be injected into the jugular vein, they destroy or injure the red corpuscles with which they meet, and the blood containing dissolved red corpuscles and bile-acids is quickly brought to the left side of the heart and thence into the coronary arteries. This blood is unfit for the exchange of oxygen with the muscular substance of the heart, as the red blood-corpuscles are so much injured; and it is to the consequent change in the muscular walls of the heart that Traube apparently attributes the slow pulse of jaundice.

About the same time Johannes Ranke, in the course of his researches into the phenomena of tetanus, arrived at the conclusion that the bile-acids have a paralyzing action upon the striped muscular tissue, and that it is solely by the action of these acids upon the muscular fibres of the heart that the slow pulse is caused*. He agrees with Traube in opposition to Röhrig and Landois†.

I have repeated most of the experiments of those who have gone before me; but those only will be detailed which seem to throw a new light upon the matter in hand.

The bile-acids employed in these researches were prepared from ox-gall by a slight modification of the process recommended by Kühne‡. I have to thank my friend Dr. Shuter, of Caius College, Cambridge, Assistant Demonstrator of Physiology in St. Bartholomew's Hospital, for his kindness in preparing for my use some of the bile-acids used in these experiments. In nearly all instances the bile-acids were dissolved in distilled water, 10 per cent. in strength. I should mention that the acids were not separated from their combination with soda.

My first experiments were directed altogether to the heart of the frog, which lends itself readily to researches of this kind, as it can be separated from its attachments, and its contractions kept up by being fed with serum by means of an artificial circulation. In this way I attempted to decide if the slow pulse be due to an excitement of the ends of the vagus in the heart.

The heart of a frog being arranged in Bowditch's apparatus§, the following observations were taken:—

* Arch. f. Anatomie u. Physiologie, 1864, p. 340; also in 'Tetanus' (Leipzig, 1865) p. 395.

† Landois, 'Deutsche Klinik,' 1863, no. 46, p. 449.

‡ Lehrbuch d. phys. Chemie (Leipzig, 1866), p. 75.

§ For a description of this apparatus see Dr. Lauder Brunton's 'Experimental Investigation of the Action of Medicines,' London, 1875, p. 72.

Time in seconds.	Pulsations.	Height of curve in millimetres.	Remarks.
In 130	31	5·5	
,,	32	6	
,,	38	4	Curves are double-topped.
,,	31	6	Atropia introduced into serum so that it contained ·028 per cent.
30	6	7	Bile-acids (serum containing 1 per cent.) now introduced.
,,	4	7	Records in continuous 30 seconds.
,,	4	8	The pulse now goes in pairs, $6^{s}\cdot5$ between each pair of pulsations. Between the pulses of each pair $3^{s}\cdot2$.
,,	4	8·5	These do not go in pairs.
,,	4	9	
,,	4	8	These go in pairs.
130	13	12	A great change in the character of curves. Systole reaches maximum height, = 6 millims., in $1^{s}\cdot5$. They slowly sink, scarcely meeting abscissa until next contraction begins. Nearly all alike. One takes up 23 millims., others 38 millims.
,,	12·5	10	Immediately after this the heart ceases to beat: no contractions upon electrical irritation.

Four other like experiments with the like results were made: in one of them the bile-acids were added to the serum first, and the atropine added afterwards; but the same results were attained. The slowness of the pulse arose as before, and was unchanged by the addition of the atropine. If it be true, then, that atropine paralyzes the ends of the vagus in the heart, it would appear that the slow pulse is not due to any excitement of the ends of these nerves in the heart. The great height of the curves just before the heart ceased to beat does not favour, either, the belief that the slow pulse is due to a weakening of the muscular walls.

In order to test the foregoing experiments, I made further experiments upon the irritability of the vagus in poisoning by the bile-acids.

The heart and vagus of a frog laid bare. Heart beating 12 in 15^{s}. The right vagus then irritated by induced electricity: the heart stood still in diastole. Three or four drops of the pharmaceutical solution of atropine now let fall upon the heart. Five minutes after the beats were 7 in 15^{s}. The right vagus was then again irritated by induced electricity, with no change in the heart. After ten minutes, four drops of a 10-per-cent. solution of bile-acids were let fall upon the heart and neighbourhood. Thereupon, for nearly a minute, the heart-beats rose to 10 in 15^{s},

but directly after fell to 6 in 15^s. Five minutes after, the beats being still 6 in 15^s, the right vagus was again irritated, but no change followed. Three minutes after the beats were 5 in 15^s. Experiment was then broken off.

Two other like experiments were made and with like results. They would seem to show that the bile-acids do not restore to the vagus the inhibitory power destroyed by the atropine.

If, then, the slowness of the pulse be not due to the influence of the vagus on the heart, there remain two other factors in the movements of the heart to be considered—the ganglia and the muscular walls. Looking at the muscular walls as the cause of the slow pulse, it became of great importance to examine with care the experiments of Traube and Johannes Ranke, as to the action of the bile-acids upon striped muscular tissue. Traube himself has made no immediate observations upon muscle. He believes that the heart muscle is the organ affected, solely apparently because the low blood pressure and slow pulse so quickly disappear. I can confirm nearly all Traube's statements of fact by observations of my own. Only the ecchymoses in the conjunctiva of the side used for injection have I failed to see. The inspiratory spasm on the injection of the bile-acids into the carotid is extremely well marked, and persists after the removal of the cerebral hemispheres. But it is hard to agree with his explanation of facts, and his "muscular-motor" theory remains at present a pure hypothesis.

In repeating Ranke's experiments I followed his method of injecting 10 cubic centimetres of a 1-per-cent. solution of bile-acids in saline solution into the aorta of frogs. I noticed all the phenomena which he has described—the irregular contractions of the muscles of the limbs as the injection passed into them, their rigidity and hardness immediately after the injection, and the absence of contraction on the application of electricity to the sciatic nerves. Ranke seems to think these appearances are best explained by supposing that the bile-acids have a specific influence upon muscular tissue. Knowing, however, the power which the bile-acids possess of coagulating albumen (a 1-per-cent. solution will coagulate white of egg), it seems to me that the appearances seen would be very fully explained by the chemical action of the bile-acids upon the albuminous substances of the muscle; and a chemical action Ranke himself admits. I was thus led to make a series of experiments in which the bile-acids should not be immediately brought into contact with the muscles, but should act by means of the natural process of absorption. The bile-acid solution was injected into the lymphatic sac or under the skin of frogs. The amount given varied from ·05 to ·3 grm. Twelve experiments were made, and in nearly all no change in the curve traced by the myograph could be detected after the injection of the bile-acids, the observations lasting up to the time that the muscles responded to any amount of electricity that I was able to bring to bear upon them.

The method used was as follows: the sciatic nerve was prepared, carefully avoiding all injury of blood-vessels; the tendon of the gastrocnemius was attached to a string, and separated from the heel. The frog was then put into a moist chamber, and the string attached to the tendo Achillis fastened to a telegraph lever writing on a revolving cylinder. The sciatic nerve was then irritated by means of electricity from a Du-Bois-Reymond's coil; it was applied not oftener than once every 60^s, and only of such amount as to cause the muscle to contract.

I here extract from my experiment-book a few experiments detailed at length.

Jan. 22.—Excellent normal curves obtained. ·1 grm. of bile-acids injected under skin of back: no change in the curves, save that they grow smaller in height from 15^m to 60^m after the injection.

Feb. 2.—·3 grm. of bile-acids injected into the lymph-sac of frog: no change from normal curves from 16^m to 92^m after the injection.

In three of these experiments changes in the natural curve were noticed after the injection of the bile-acids. The same appearance was seen in all three, namely, that the muscle was a long time in recovering itself. The down stroke of the muscle curve took some space before it reached the abscissa. In two of these cases, however, the muscle curves taken before the injection of the bile-acids showed the same appearance. After the injection the prolongation of the curve became somewhat more marked, varied by returns to almost normal markings. It is thus impossible to attribute any weight to these variations. The amount of bile-acid given in these two cases was ·2 and ·3 grm. respectively. In the third case in which this lengthening of the curve was noticed no markings were taken before the injection, so that from this case it is again impossible to draw any inference. The amount of bile-acid given was ·3 grm.

If, then, the bile-acids have no physiological action upon striped muscular tissue, have they yet any chemical influence upon the ventricle alone? I thought, therefore, of making some experiments upon the action of the bile-acids on the ventricle when separated from the rest of the heart. It is commonly said that the ventricle of the frog's heart continues to beat for some time after it be severed from the auricles. I found, however, that the time was not long enough, nor the beating of the ventricle constant enough, to enable me to judge of the difference in time taken to bring the ventricle to a standstill if immersed in serum, or in serum containing 1 per cent. of bile-acids. I therefore fell back upon a method lately employed by Luciani*. It consists in introducing into the ventricle of the frog's heart a tube divided vertically by a septum, and tying the ventricle on to the cannula below the auricles. The heart is supplied by serum through the double cannula, and each

* Arbeiten aus d. phys. Anstalt zu Leipzig, Jahrg. vii. 1873, p. 120.

pulsation is recorded by a manometer*. I made five of these experiments, but could detect no change in the alternate standstill and tetanus, described by Luciani, after the introduction of bile-acids in 1 per cent. into the serum, nor after the removal of the bile-acid serum and the feeding of the heart with pure serum. Both before and after the use of the bile-acids the contractions of the ventricle were the same. It would seem, therefore, that the bile-acids have no influence, either chemical or physiological, upon the ventricle of the frog's heart separated from the auricles.

If, then, the bile-acids have no influence upon the ends of the vagus in the heart, nor upon the muscular tissue, there remains, in the present state of knowledge, only one other cause of the heart's movement which may beget a slow pulse, viz. the ganglia of the heart. Arguing, therefore, *per viam exclusionis*, the same conclusion is reached as that of Röhrig, viz. that it is the action of the bile-acids upon the ganglia of the heart which causes the slow pulse in jaundice. The same conclusion is come to, but upon altogether different grounds; for it must be acknowledged that the grounds upon which Röhrig formed his opinion seem, in the present state of physiology, to be insufficient.

I have also made some experiments upon the influence which the bile-acids have upon the rate of pulsation of the lymphatic hearts of frogs. The rate does not seem to be in any way influenced by the bile-acids. The heart only begins to beat more slowly where general death is setting in from the action of the poison. The blood-heart, on the contrary, begins to feel the influence of the poison within a few minutes of its injection, and the pulsations may sink from 13 to 3 in 15^s in seven minutes after the injection of 1 cubic centimetre of the bile-acid solution under the skin.

I have made six observations upon the lymph-hearts, of which I add the details of one.

Dec. 24th.—Right posterior lymphatic heart exposed at 10.55 A.M. The pulsations vary from 7 to 9 in 15^s. At 11.5 the average is 9 in 15^s. At 11.7 one cubic centimetre of bile-acid solution was injected under the skin of the neck.

At 11.12 A.M. 10 in 15^s.	At 12.20 P.M. another injection.
11.15 „ 9 „	12.25 „ 11 in 15^s.
11.20 „ 9 „	12.31 „ 10 in 16^s.
11.24 „ struggles.	12.35. Lymph-hearts now ceased to act.
11.28 „ 9.	2.0 P.M. Animal found dead.
12 noon 10 in 15^s.	

I have likewise made some observations upon the changes in the reflex

* The double cannula is called by the Germans *Froschherzventrikelbestimmungs-apparat*, and may be had of Hornn, the instrument-maker in Leipzig. The one sent by him to me was, however, too large for the hearts of English frogs, and a smaller one on the same plan was made for me by Hawksley, of Oxford Street.

movements which follow the administration of the bile-acids. I choose one of five experiments nearly all alike.

Dec. 19*th*.—The anterior cerebral hemispheres of a frog, leaving the optic thalami uninjured, removed. The foot was irritated by being plunged in water made just perceptibly acid to taste by sulphuric acid. The numbers are in seconds.

12.22. 12, 6, 7, 8, 6, 7, 6.

12.32. ·5 cubic centimetre of bile-acid solution injected under the skin of the back.

12.39. 1, 2, 1, 1, 29, 27, 15, 16, 21, 28, 22, 26.

The head cut off at 1 o'clock.

1.25. 9, 9, 9, 9, 10, 10, 10.

In all cases a minute passed between the application of the irritant, and the foot was well washed with distilled water after each observation.

From these observations it would appear that the reflex irritability is greatly diminished by the bile-acids.

In conclusion I wish to express my best thanks to Professor Burdon Sanderson, F.R.S., and to Dr. Lauder Brunton, F.R.S., for their great kindness in giving me invaluable advice and assistance throughout the research. Many of the experiments were made in the Jodrell Laboratory at University College, London, under Professor Burdon Sanderson's eye; and the remainder were made in the Pharmacological Laboratory of my friend and colleague Dr. Lauder Brunton, at St. Bartholomew's Hospital.

III. "On the Structure of a Species of *Millepora* occurring at Tahiti, Society Islands." By H. N. Moseley, Naturalist to the 'Challenger' Expedition. Communicated by Prof. Wyville Thomson, F.R.S., Director of the Civilian Scientific Staff. Received March 6, 1876.

(Abstract.)

In a paper treating mainly of the structure of *Heliopora cærulea*, communicated to the Royal Society in the autumn of 1875, some account was given of results arrived at from the examination of two species of *Millepora* obtained at Bermuda and at Zamboangan, Philippines; and in that paper a summary of the literature concerning the tabulate corals generally was given. The present paper, to be considered to a certain extent a continuation of the last, gives an account of the structure of a species of *Millepora* obtained at Tahiti, Society Islands. The author commences by expressing his obligations to his colleague Mr. J. Murray, who obtained living specimens of the *Millepora* and handed them over to him with the zooids in the expanded condition for examination, and who further, having devoted some time to the study of the coral, gave him valuable information with regard to several points in its structure.